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I, LISA TREVERROW, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PQ 4877 for a patent by POSEIDON SCIENTIFIC INSTRUMENTS PTY LTD filed on 23 December 1999.

WITNESS my hand this
Twenty-fifth day of January 2001

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Lisa Treverrow

LISA TREVERROW
TEAM LEADER EXAMINATION
SUPPORT AND SALES

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ORIGINAL

AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Invention Title: Multi-layer Microwave Resonator

The invention is described in the following statement:

TITLE

Multi-Layer Microwave Resonator

FIELD OF THE INVENTION

This invention relates to a multi-layer microwave resonator.

BACKGROUND ART

Modern radar and telecommunications systems require high frequency signal sources and signal processing system with stringent performance requirements and extremely good spectral purity. Thus, there is a need for signal processing systems and signal sources with ever increasing spectral purity, stability and power-handling requirements.

Resonators, by their nature, provide discrimination of wanted signals from unwanted signals. The purity and stability of the signals produced is directly linked to the resonator used as the frequency determining device and is dependant upon its Q-factor, power handling ability and its immunity to vibrational and temperature related effects.

It is known that a piece of dielectric material has self-resonant modes in the electromagnetic spectrum that are determined by its dielectric constant and physical dimensions. The spectral properties of a given mode in a piece of dielectric material are determined by the intrinsic properties of the dielectric material, its geometric shape, the radiation pattern of the mode and properties and dimensions of the materials surrounding or near the dielectric material.

Prior art resonators have traditionally relied on metallic cavities containing no dielectric material, or on metallic cavities containing a dielectric material which were limited in Q-factor by the properties of the metallic cavities and hence were operated at cryogenic temperatures in order to obtain a better Q-factor.

However, to maintain cryogenic temperatures requires equipment which is cumbersome and difficult to incorporate into a portable or compact apparatus.

US Patent 5,712,605 to Flory and Taber describes another resonator structure that seeks to address these problems. The resonator described in US Patent 5,712,605 is a complex stack of hollow cylinders and flat discs formed of dielectric material. The cylinders and discs are enclosed within a metal cavity. The length of the cylinders and the diameter of the discs determine the operating mode of the resonator. The resonator is described as offering a high Q-factor. The hollow cylinders and discs form a series of axially aligned cavities. Although the resonator described in US Patent 5,712,605 offers a high Q-factor, there are several disadvantages associated with the resonator structure. These include the difficulty of manufacture and its sensitivity to vibration. The device is difficult to manufacture because the hollow cylinders must be perfectly coaxial or the operation of the resonator will be significantly impaired. Further, because the resonant cavities are defined by the dielectric discs and hollow cylinders, any vibration or movement induced in one or more of the dielectric hollow cylinders or discs will result in a corresponding change in the shape of the resonant cavity, with a resulting change in the resonant frequency. This is referred to as mode breaking and has limited the usefulness of this resonator structure.

DISCLOSURE OF THE INVENTION

Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

In accordance with the first aspect of this invention, there is provided a multi-layer microwave resonator, comprising:

> a cavity having an inner surface formed from an electrically conductive material;

a plurality of pieces of dielectric materials stacked on top of each other to form a contiguous body, the body being provided in the cavity;

wherein the pieces of dielectric materials are arranged such that the dielectric constant of the pieces alternate between a relatively high dielectric constant and a relatively low dielectric constant.

Preferably, the body includes a central piece of dielectric material having a relatively low dielectric constant.

Preferably, the central piece has a length commensurate with an integer multiple of one-half wave length of a desired operating frequency in the dielectric material.

Preferably, the cavity comprises a wall and ends, the body being contained between the ends of the cavity.

In one arrangement, the cavity wall is spaced from the body.

In an alternative arrangement, the cavity wall abuts the body.

Preferably, the pieces of dielectric material are substantially cylindrical.

Preferably, the dielectric materials are sapphire and rutile.

In one arrangement, the pieces of dielectric material formed of rutile have an aperture formed centrally therein.

Preferably, the central body has an opening formed therein for receiving test substances.

In one arrangement, the said body is formed of three pieces of dielectric materials, arranged as a central piece of a first dielectric material and two end pieces of a second dielectric material, the central piece of dielectric material having a length commensurate with an integer multiple of one-half wavelength of a desired operating frequency in said first dielectric material, the end pieces

having a length commensurate with an odd integer multiple of one-half wavelength of the desired operating frequency in the second dielectric material, wherein the dielectric constant of the second dielectric material is greater than the dielectric constant of the first dielectric material.

In an alternative arrangement, the body comprises five pieces of dielectric materials, wherein the pieces of dielectric material having a relatively high dielectric constant have a length commensurate with an odd integer multiple of one quarter wavelength of a desired operating frequency in that dielectric material, the central piece being formed of a dielectric material having a low dielectric constant and having a length commensurate with an integer multiple of one half wavelength at the desired operating frequency in that dielectric material, the end pieces being formed of a dielectric material having a relatively low dielectric constant and having a length commensurate with an odd integer multiple of one quarter wavelength of the desired operating frequency in that dielectric material.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be better understood with reference to the following description of four specific embodiments thereof and the accompanying drawings, which;

Figures 1(a) and 1(b) are elevation and plan cross-sections, respectively, of a multi-layer microwave resonator in accordance with a first aspect of this invention;

Figures 2(a) and 2(b) are elevation and plan cross–sections, respectively, of a multi-layer microwave resonator in accordance with a second embodiment of this invention;

Figures 3(a) and 3(b) are elevation and plan cross-sections of a multi-layer microwave resonator in accordance with a third embodiment of this invention; and

Figures 4(a) and 4(b) are elevation and plan cross-sections of a multi-layer microwave resonator in accordance with a fourth embodiment of the invention, in

which Figure 4(a) also includes a illustrative representation of electro-magnetic fields within the microwave resonator.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

The embodiments are directed towards multi-layer microwave resonators which can be used in a variety of applications. The microwave resonators are intended to provide a relatively high Q-factor and operate in a low order mode to reduce spurious modes. The relatively solid constructions reduces the vibrational sensitivity of the device.

The first embodiment is directed towards a microwave resonator 10 comprises a cavity 12 and a body 14 that is formed from five pieces of dielectric material 16(a)-16(e) stacked on top of each other, as shown in Figures 1a and 1b

The cavity 12 comprises a cylindrical wall 18 and two end sections 20(a) and 20(b). The cylindrical wall 18 and the end sections 20(a) and 20(b) are formed from copper. In other embodiments, the wall end in sections may be formed from other electrically conductive materials, or may have an inner surface coated with such a material. For best performance, it is preferred that the electrically conductive material have a low impedance, such as silver or copper.

The body 14 is provided within the cavity 12 coaxially with the cylindrical wall 18. The body 14 is held in place between the end sections 20(a) and 20(b). If desired, recesses of an appropriate shape may be formed in the end sections 20(a) and 20(b) to more securely hold the body 14 in position within the cavity 12. The cylindrical wall 18 is spaced from the body 14 in the embodiment to define an annular air filled or vacuum space 22.

Each of the pieces of dielectric material 16(a)-16(e) are solid cylinders in shape in the embodiment. The piece 16(c) forms a central piece of the body 14, having pieces 16(b) then 16(a) stacked on top of it and pieces 16(d) and 16(e) stacked below it.

The pieces 16(a), 16(c) and 16(e) are formed of sapphire as the dielectric material. The pieces 16(b) and 16(d) are formed with rutile as the dielectric material. Rutile is known to have a higher dielectric constant than sapphire and so, in relative terms, the dielectric constant in the body goes as low, high, low, high, low. In this regard, what is important is that the dielectric constant of the dielectric material from which the pieces 16(b) and 16(d) are made from is higher than the dielectric constant of the dielectric material from the layers 16(a), 16(c) and 16(e) are made from, rather than their absolute values.

The length in the axial direction of each of the pieces of dielectric materials 16(a)-16(e) is determined according to the wavelength of a desired operating frequency within the respective piece of dielectric material. In this regard, the central piece 16(c) has an axial length corresponding with one half wavelength at the desired frequency, the pieces 16(b) and 16(d) have an axial length corresponding with one quarter wavelength of the desired frequency, and pieces 16(a) and 16(e) each have a length corresponding with one quarter wavelength at the desired frequency. Although the axial length of the central piece 16(c) can be any multiple of one half wavelength, and the axial length of pieces 16(a), 16(b), 16(d) and 16(e) can be any odd multiple of one quarter wavelength, it is preferred that a single multiple is used to minimise spurious modes. It also minimises the size of the device where a space is at a premium.

The operating frequency of the microwave resonator 10 can be tuned a follows. Firstly, course tuning can be achieved by selecting the axial length of each of the pieces of dielectric materials 16(a)-16(e) as described above. However, the machining process that creates the pieces 16(a)-16(e) is not accurate enough to achieve exact dimensions. Thus, medium frequency tuning can be achieved by adjusting the diameter of the cylindrical wall 18, such as by machining. Fine adjustment of the operating frequency can be achieved by temperature regulation.

The second embodiment is shown in Figures 2(a) and 2(b). Figure 2(b) is a cross-section through lines A-A in Figure 2(a). The second embodiment is directed towards a multi-layer microwave resonator. 110 of the same general form as the microwave resonator 10 described in the first embodiment. Like

reference numerals are used to denote like parts to those shown in the first embodiment, with 100 added thereto.

The multi-layer microwave resonator 110 differs from the microwave resonator 10 in the first embodiment in that the pieces 116(b) and 116(d) of rutile each have a circular aperture 124 formed therein. The aperture 124 can be left empty or filled with a very low loss, low dielctric constant dielectric material.

The third embodiment is directed towards a multi-layer microwave-resonator 210, as shown in Figures 3(a) and 3(b). Like reference numerals they used to denote like parts in those in the first embodiment, with 200 added thereto.

The microwave resonator 210 differs from the microwave resonator 10 in the first embodiment in that the body 214 in the second embodiment is formed from nine pieces 216a-216i of dielectric materials. In the current embodiment, the piece 216e forms the central piece of the body 214, with pieces 216d, 216c, 216b and finally 216a stacked on top of it and pieces 216f, 216g, 216h and finally 216i stacked below it. The pieces 216a, 216c, 216e, 216g and 216i are formed from sapphire. The pieces 216b, 216d, 216f and 216h are formed rutile. Each of the pieces 216a-216d and 216f-216i have an axial length commensurate with one quarter wavelength in the corresponding dielectric material. Increasing the number of layers offers a higher Q-factor, but at the expense of increased complexity of manufacture. Conceptually, further pieces of dielectric material can be added to a body ad infinitum, but each subsequent piece offers diminishing returns.

Further, in the microwave resonator 210 of the current embodiment, the cylindrical wall 18 abuts the body 214.

The fourth embodiment is directed towards a microwave resonator 310, shown in Figures 4(a) and 4(b). Like reference numerals they are used to denote like parts to those used in the first embodiment, with 300 added thereto.

The microwave resonator 310 in the current embodiment is of the same general form as the microwave resonator 10 in the first embodiment, the only difference being that the diameter of the pieces 316a-316e are greater than the corresponding pieces 16a-16e in the first embodiment. Further, the wall 318 abuts the body 314 in this embodiment.

The lines marked B in Figure 4(a) offer an illustrative representation of the electro-magnetic field present in the resonator 310.

It should be appreciated that the scope of this invention is not limited to the particular embodiments described above.

For example, the multi-layer microwave resonator can be made with more than 7 layers or less than 5, as desired. Further, the diameter of the pieces of dielectric material 16(a)-16(e) can be adjusted according to requirements.

Further, it is envisaged that an opening can be provided within the body 14, preferably within the central piece 16(c) to receive test substances therein in order to examine the effects of exposure to microwave energies.

Further, it is envisaged that other dielectric materials than sapphire and rutile can be used.

Dated this twenty-third day of December 1999

Poseidon Scientific Instruments Pty Ltd and
The University of Western Australia
Applicants

Wray & Associates
Perth, Western Australia
Patent Attorneys for the Applicant(s)

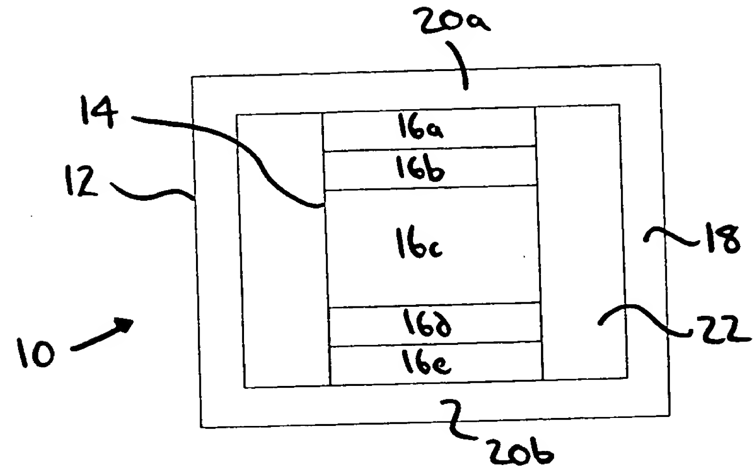


Fig. 1a

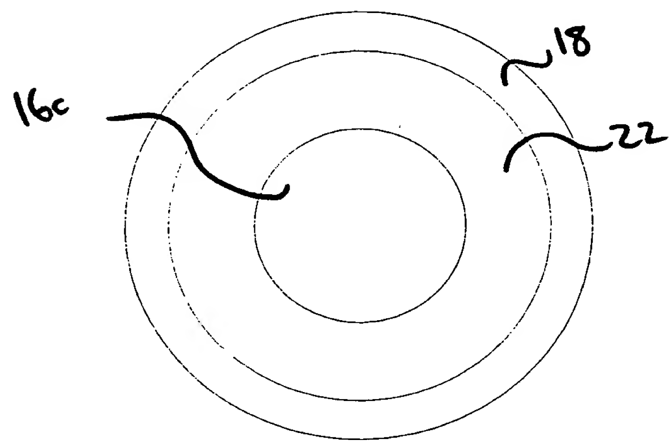


Fig 1b.

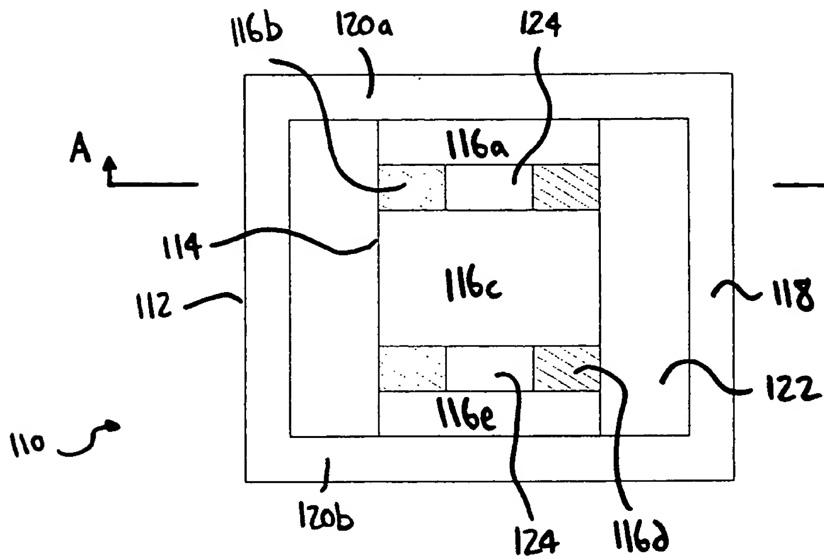

116b
120a
124
A
A
116a
114
116c
112
118
122
110
116e
120b
124
116d

Fig 2a

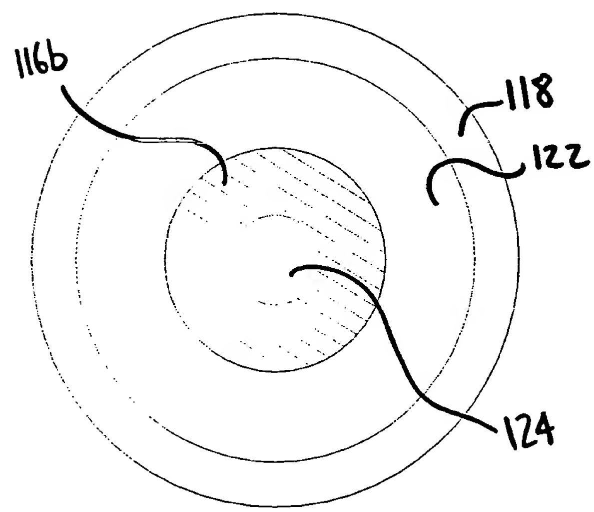
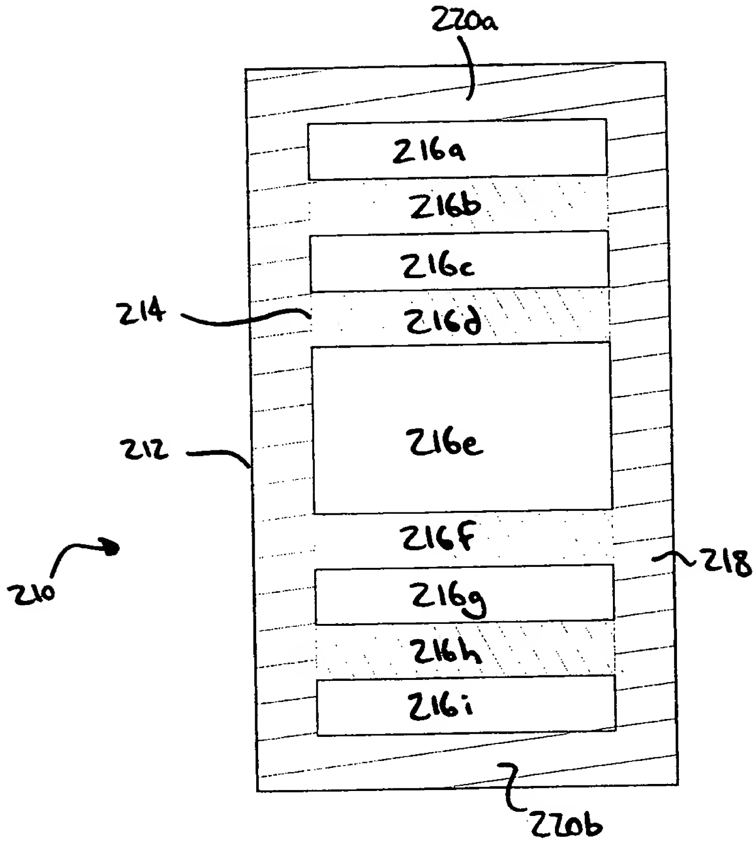
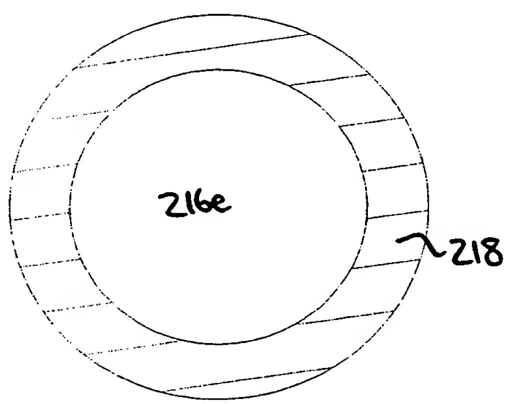

116b
118
122
124

Fig 2b



220a
216a
216b
216c
214
216d
216e
212
216f
218
216g
210
216h
216i
220b

Fig 3a



216e
218

Fig 3b

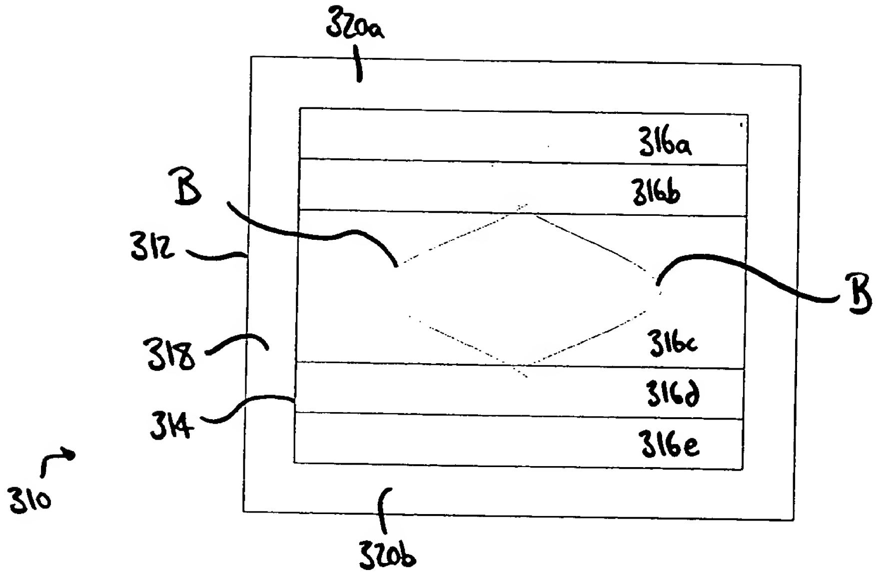


Fig 4a

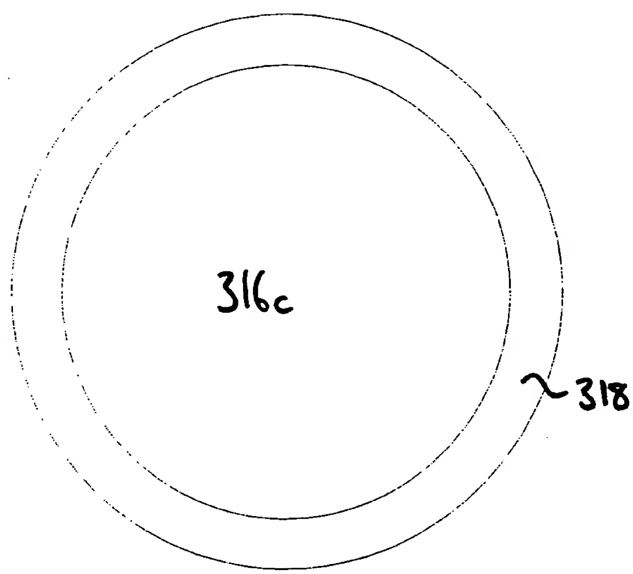


Fig 4b